as recited in the claims, is constant over the entire cross section of the inner ring, the outer ring, and the rolling element. This fact is also available in the prior art.

The specification as originally filed discloses hardening and tempering of the bearing components. For example, the original specification recites:

> "At first, ball bearings each of 5 mm inner diameter, 15 mm outer diameter and 4 mm width, and having a ball diameter of 2 mm were manufactured as described below. The inner rings and the outer rings were manufactured by repairing formed products of a predetermined shape using steel materials for each of the compositions indicated by A-V shown in the following Table 1, then applying hardening at 860°C and successively applying tempering at 240°C for 2 hours to each of the formed products. The surface hardness (HRC) and the amount of the residual austenite (γ_R) after the heat treatment are shown together in Table 1. For all of the rolling elements, balls made of SUJ2 used so far were used." (See lines 5-16, page 13.)

As shown in the attached Japanese references, it is in the prior art that the residual austenite obtained by hardening/tempering is constant over the entire cross section of the inner ring, the outer ring, and the rolling element. An English translation of the relevant sections of the references has been attached.

Reference 1 is entitled "Fatigue Analyses of the Rolling Bearing" and can be found in NSK BEARING JOURNAL 643, November 1982. Reference 1 recites that "[i]n this study, a fatigue level is measured in the X-ray diffraction method, and

three factors of residual stress, diffraction line half value breadth, and the amount of residual austenite which definitely change with rolling contact fatigue are measured using X-ray." See page 2, lines 24 to line 27 (marked "A") in Reference 1.

The result of the examination is shown in Figure 3 on page 5. Figure 3 shows that the internal distribution of X-ray measurements of the inner race before the test (Cylindrical roller bearing NU2206, ball bearing HR6304). The amount of the residual austenite with respect to the depth measured from the surface is shown in the bottom figure of Figure 3. As shown in the bottom figure, the amounts of residual austenite in the cylindrical roller bearing NU2206 and ball bearing HR6304 are constant at about 8 vol% at least within 10 μm from the surface.

The materials of the cylindrical roller bearing NU2206 and ball bearing HR6304 are not explicitly disclosed in Reference 1, these materials will be described with reference to Reference 2 (Rolling bearing Engineering, 1976, YOUKENDOU).

On pages 60 to 61 (marked "B"), Reference 2 recites:

"3.2 Material of Raceway Ring and Rolling Element

From the characteristics of the materials, the material of the raceway ring and the rolling element has to be sufficiently hard. In this respect, the hardness of about HRC 60 (Hv 700) can be easily obtained by using hardened steel by low temperature tempering."

In addition, on page 61 to 62 (marked "C"), Reference 2 recites:

"3.2.1 Through Hardened Steel

Initially 6, carbon steel has been used to obtain the hardness by hardening. At the beginning of the 20th century (it is noted that the translation includes a typographical error in saying "21st" century), high-carbon low-chrome steel (1%C, 1.5%Cr) which is still used as the material of the majority of the rolling bearings was developed. Since then, for a long period over a half century, the material has been used with the most basic ingredients unchanged. No other steel for a single use can be unchanged, and the material is most preferable at the normal temperature."

Further, the main ingredient of the standard bearing steel in Japan is shown in Table 3.2 of Reference 2.

Further, Reference 1 points out that "since the half value breadth, and the amount of residual austenite in a steel bearing indicates substantially constant for the portions other than the surface process affected layer, the precision of a predicted reference value is high." See page 5, lines 8 to 10.

On the basis of the materials cited from Reference 2, it is clear that the materials of the cylindrical roller bearing NU2206 and the ball bearing HR6304 are SUJ2 or perfect hardened steel with low carbon. Therefore, it is obvious that the amount of the residual austenite in perfect hardened steel obtained by hardened/tempering is constant at about 8 vol% at least within 10 μm from the surface. In other words, the amount of the residual austenite in perfect hardened

steel obtained by hardened/tempering is constant on the surface and in the center portion of the bearing steel.

The Examiner rejected Claims 1, 2 and 4 under 35 U.S.C. 103(a) as being unpatentable over Matsumoto et al. With respect to Claim 1, the Examiner took the position that in view of Matsumoto et al. and the prior art, it would be obvious to one having ordinary skill in the art to find the limitation "the amount of residual austenite is 0% by volume" to be optimum. With respect to claim 2, the Examiner considered that Matsumoto et al. discloses steel with ranges which overlap those of claim 2 and it would have been obvious to find the optimum range for the outer ring and rolling element. With respect to claim 4, the Examiner took the position that it is conventional in the prior art to use ceramic rolling elements with steel inner and outer rings.

Further, the Examiner rejected Claims 3 and 5-10 under 35 U.S.C. 103(a) as being unpatentable over Matsumoto et al. in view of Tanaka et al. The Examiner stated that Matsumoto et al. does not disclose nitriding after hardening and tempering, but considered Tanaka et al. discloses a close approximation to this limitation. On this basis, the Examiner concluded Claim 4 is obvious.

Before the rejections are specifically addressed, Applicants believe a general description of the cited references and the present invention are helpful.

Matsumoto et al. (U.S.P. No. 5,122,000)

Matsumoto et al. discloses the extension of the life of a rolling bearing requiring high PV values. It discloses following points:

1) The hardness of the raceway surface or rolling contact surface of the bearing is HRC in the range of 64 to 69.

2) The average concentration of residual austenite is less than 10% by volume.

In Table 7, the average concentration of residual austenite is shown to be from 0.64% to 15.2% by volume. Also, as shown in Figure 9, the concentration of residual austenite is higher at the surface and lower inside the outer ring. Therefore, it is clear that the concentration of residual austenite is about 23% by volume at the surface A and about 2 to 3% by volume inside the outer ring. As a result, the average concentration of residual austenite is about 6.4% by volume.

The dimensional stability of the bearing is better when the average concentration of residual austenite in a ball bearing is lower. The average concentration of residual austenite is determined to be less than 10% so that the dimensional stability of the rolling bearing is equivalent or superior to that of the bearing steel No.2 (SUJ-2).

3) In Matsumoto et al., the ingredients of steel specimen are as follows:

C: The C content is equal to or less than 1.5% by weight for non-casing hardening alloy steels. Further, in the case of the case hardening alloy steel, the C

content is preferably about from 0.2 to 0.6% by weight. In Table 1, the C content is from 0.20% to 1.23% by weight.

Si: In Table 1, the Si content is from 0.22% to 0.40% by weight.

Mn: The Mn content is preferably less than 2.0% by weight. In Table 1, the Mn content is from 0.43% to 0.80% by weight.

Mo: The Mo content is preferably less than 8% by weight and, more preferably, less than 2.0% by weight. In Table 1, the Mo content is from 0% to 6.13% by weight.

4) In Matsumoto et al., the heat treating method used in the examples is almost carburizing hardening by ion or gas and tempering, as shown in Tables 3, 4, 6 and 7. But, in Table 7, the outer ring No.5 (SUJ-2) is hardened and tempered.

5) The tempering temperature used in Figure 7 is 180°C and the tempering time is 2 hours.

<u>Tanaka et al. (U.S.P. No.6,086,686)</u>

Tanaka et al. disclose a rolling bearing having a plurality of rolling elements, at least one of the rolling elements being formed from a steel having secondary hardenability and a nitride layer of 2% or less of a diameter Da of a rolling element on a surface layer of a finished article.

Further, the nitride layer has Cr nitride and Fe nitride as a surface layer, and is nitrided at a temperature of 480°C or less, preferably 430°C or less. The

nitride layer can prevent adhesion, decrease friction and significantly improve fretting damage.

Present invention

The object of the present invention is to provide a rolling bearing excellent both in the rolling contact fatigue life and in the rotational accuracy and suitable for use in HDD spindles, at a reduced cost.

In order achieve this object, the rolling bearing has the following features:

1) In claim 1, the amount of residual austenite over the entire cross section of one of the inner ring, the outer ring and the rolling element is 0% by volume, and the surface hardness is HRC of 62 or more.

In claims 2, 3, 4, 5 and 11, the amount of residual austenite over the entire cross section of one of the inner ring and the outer ring and the rolling element is 0% by volume, and a surface hardness is HRC of 62 or more.

The amount of residual austenite over all cross sections of the raceway ring or the rolling element is 0% by volume, so that the dimensional change of the rolling bearing by the martensitic transformation is removed to improve the rotational accuracy of the rolling bearing, and the impact absorbing energy is increased. Also, even if the amount of residual austenite over all cross sections of the raceway ring or the rolling element is 0% by volume, since the surface hardness is HRC of 62 or more, the impact resistance of the bearing is improved so that the acoustic life is improved and the rolling fatigue life is extended.

2) In claim 1, at least one of the inner ring, the outer ring and a rolling element is formed from a steel material containing alloy ingredients each within a range of C: O.8 to 1.20% by weight (in order to obtain the surface hardness HRC of 62 or more and to suppress the residual austenite), Si: 0.60% by weight or less (in order to increase the anti-temperability and to prevent hindering decomposition of the residual austenite), Mn: 0.25% by weight or less (in order to increase the hardeability and to suppress the residual austenite), Cr: 1.00 to 1.50% by weight (in order to increase the hardenability), and Mo: 0.60 to 1.50% by weight (in order to increase the surface hardness to HRC 62 or more while reducing the amount of the residual austenite to 0% by volume by elevating the tempering temperature).

In claims 2, 3, 4, 5 and 11, at least one of the inner ring and the outer ring is formed from a steel material containing alloy ingredients each within a range of C: O.8 to 1.20% by weight, Si: 0.60% by weight or less, Mn: 0.25% by weight or less, Cr: 1.00 t o 1.5 0% by weight, and Mo: 0.60 t o 1.50% by weight.

With the definition of the steel material as described above, the surface hardness can be increased to HRC 62 or higher even when the material is hardened at high temperature as reducing the amount of the residual austenite over the entire cross section of the raceway rings or the rolling element to 0% by volume. In addition, since macro-carbides as contained in high speed steel M 50 are not present and a surface hardening treatment such as carburizing is not necessary when the steel material as defined above is used, the fabrication costs can be reduced.

3) In claims 2 and 11, the rolling element is formed from a steel material containing alloy ingredients each within a range of C: 0.3 to 0.6% by weight, Si: 0.3 to 1.5% by weight, Mn: 0.3 to 1.7% by weight, Cr: 0.5 to 2.5% by weight and Mo: 0.6 to 3.0% by weight, with O content being 9 ppm or less. It then is applied with carbo-nitridation and with hardening/tempering. The amount of residual austenite is 0% by volume, and the surface hardness is HRC of 62 or more.

Since the rolling element is formed from a steel material with less carbon content and more Mn content than the steel material (C: 0.8 to 1.20% by weight, Si: 0.60% by weight or less, Mn: 0.25% by weight or less, Cr: 1.00 to 1.50% by weight, and Mo: 0.60 to 1.50% by weight) and is applied with carbo-nitridation, the generation of vibrations can be suppressed even during high speed rotation, for example, at about 10,000 rpm to 15,000 rpm, and the acoustic life at high speed rotation can be increased.

4) In claim 3, the rolling element is formed from a maltensitic steel and is applied with hardening/tempering and then applied with nitridation to form a nitride layer at a thickness of 3μm or more on the surface and then applied with finishing to a surface roughness of 0.1μm Ra or less. With this feature, the heat resistance and the wear resistance are increased.

5) In claim 4, the rolling element is formed from ceramics.

On the basis of the above discussion of the present invention and the cited references, Applicants believe that not all limitations of the present invention as

claimed are disclosed or taught by the cited references. The differences are discussed below.

The difference between the present invention and Matsumoto et al.

1) Matsumoto et al. does not disclose that the amount of residual austenite in the raceway ring or the rolling element is 0% by volume over all cross section of the raceway ring or the rolling element.

In the present invention, the amount of residual austenite in the raceway ring or the rolling element of the present invention is 0% by volume over all cross section of the raceway ring or the rolling element. On the other hand, the concentration of residual austenite in the raceway ring or the rolling element of Matsumoto et al. is 10% by volume or less using the mean value from the front surface to the back surface.

In Matsumoto et al., the average concentration of residual austenite (% by volume) in the outer ring was measured after the heat treatment and the measurement results are shown in Table 7. Also, Figure 9 shows, based on the results of Table 7, that the concentration of the residual austenite varies with the position (A-B) along the direction of the thickness in the cross section of the outer ring.

As shown in Figure 7, the average concentration of the residual austenite (% by volume) in the outer ring was from 6.4% t o 15.2%.

As shown in Figure 9, the concentration of residual austenite is higher at the surface and lower inside the outer ring. Therefore, it is clear that the concentration of residual austenite is about 23% by volume at the surface A and is about 2 to 3% by volume inside the outer ring. As a result, the average concentration of residual austenite is about 6.4% by volume.

Further, the tempering temperature in Matsumoto et al. is 180°C x 2hr, as shown in Figure 7. For example, the outer ring 5 (SUJ-2) is hardened at 840°C x 0.5 hr and tempered at 180°C x 2hr.

On the other hand, in Figure 2 of the present invention, when the tempering temperature is 230°C or higher, the value of the residual austenite is reduced to 0 for all of the formed product including each of the steel materials indicated by A-P. Therefore, in order to set the amount of residual austenite in the raceway ring or the rolling element to 0% by volume over all cross section of the raceway ring or the rolling element, it is necessary to make the tempering temperature into 230°C or more.

Therefore, even if the outer ring 5 (SUJ-2) is hardened at 840°C x 0.5 hr and tempered at 180°C x 2hr, the amount of residual austenite in the outer ring 5 over all cross section of the outer ring 5 is not 0% by volume.

2) The ingredients of the Matsumoto steel specimen:

C: The C content is equal to or less than 1.5% by weight for non-casing hardening alloy steels. Further, in the case of the case hardening alloy steel, the C

content is preferably about from 0.2 to 0.6% by weight. In Table 1, the C content is from 0.20% to 1.23% by weight.

Si: In Table 1, the Si content is from 0.22% to 0.40% by weight.

Mn: The Mn content is preferably less than 2.0% by weight. In Table 1, the Mn content is from 0.43% to 0.80% by weight.

Mo: The Mo content is preferably less than 8% by weight and, more preferably, less than 2.0% by weight. In Table 1, the Mo content is from 0% to 6.13% by weight.

However, in Table 1, Matsumoto et al. does <u>not</u> disclose a steel specimen which satisfies simultaneously the range of C (0.80 to 1.20%) and the range of Mo (0.60 to 1.50%) of the present application. As shown in Table 1, only the specimen A satisfies the range of Cr (1.00 to 1.50%) of the present invention. That is, Matsumoto et al. does <u>not</u> disclose a steel specimen whose surface hardness can be increased to HRC 62 or higher even when the material is hardened at high temperature to reduce the amount of residual austenite over the entire cross section of the raceway rings or the rolling element to 0% by volume.

<u>The difference between the present invention and Tanaka et al.</u>

Tanaka et al. does not disclose the amount of residual austenite in the raceway ring or the rolling element.

While Applicants believe that the cited references do not disclose or teach all limitations of the claimed invention, Applicants also believe that combining

Matsumoto et al. and Tanaka et al. in a rejection under 35 U.S.C. 103(a) is improper, because no suggestion or motivation to combine the cited references was provided.

The rejection of Claims 6-10 is now moot in view of the cancellation of the claims.

On the basis of the above discussion, Applicants respectfully request that the rejections under 35 U.S.C. 103(a) be reconsidered and withdrawn.

If there are any questions regarding this amendment or the application in general, a telephone call to the undersigned would be appreciated since this should expedite the prosecution of the application for all concerned.

If necessary to effect a timely response, this paper should be considered as a petition for an Extension of Time sufficient to effect a timely response, and please charge any deficiency in fees or credit any overpayments to Deposit Account No. 05-1323 (Docket #313MC/48531).

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Respectfully submitted,

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